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SHAPE CHARACTERISTICS OF TARGETS IMBEDDED IN A TEXTURED BACKGROUND

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Shape Characteristics of Targets Imbedded in a Textured Background" submitted by Paul Oren McGaffey in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

Circular targets were located on a horizontal surface at 5 distances from the observer. Shape judgements were made as target texture was altered. Shape differences occurred as texture gradients varied. Decreasing surface texture did not produce inaccurate, unstable judgements of shape, and did not alter shape judgements toward retinal shape proportions. Horizontal and vertical gradients of retinal stimulation, expected to give equivalent impressions of distance and slant were not equally effective. Results are discussed in terms of J. J. Gibson's theory.

Dr. Tom,

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The General Concept of Shape

Webster's Third International Dictionary defines object shape as "spatial form or contour, that is usually fixed by relatively constant spatial relation between the parts of the periphery or surface." This definition of shape suggests a self-contained quality of things determined by the relations existing between parts. This is what Gibson (1950a, p. 34) calls "depth shape" or "that shape of an object which remains constant from whatever direction it is viewed." Nelson (1962) has argued that three types of discriminations are possible in viewing a structured field. One is a discrimination of a boundary separating two surfaces. In this simpliest case the boundary is continuous. This is called the "edge" characteristic of object perception. The other two discriminations are of surfaces. Surfaces external to the edge constitute the perceptual background. Those internal to the edge constitute the shape of the object.

Shape as Psychological Response

Only once in discussing shape and its cognates does Webster's Dictionary include mention of background: "Profile stresses the sharply outlined shape of something especially as seen against a lighter background." This lack of attention to background seems to be a serious omission, considering the basic importance attached to the figure-ground concept by psychologists studying perception. As Nelson & Bartley (1962, p. 67) point out, "an observer (0) can never

claim to see the shape of any object without also seeing its surround." Rather than attributing shape to an object segregated from its background, this paper will follow Nelson & Bartley (1962) in using the term shape to denote a discriminative response. Shape will be said to be a discrimination of a surface internal to a boundary or confluence between two parts of a field.

Shape as an Experimental Operation

Shape discriminations are customarily defined either by visual matching or by reproduction (drawing). Shape indices obtained by these two operations are highly correlated (Thouless,1932) indicating that drawing skills are minimally important when considering shape response accuracy. Drawing may even produce a more accurate shape response since it does not seem to vary with changes in the orientation of the surface carrying the match (Nelson, 1953). Further, when the effect of surround on target shape is being studied, drawing has a unique advantage over matching since "locating the edge necessitates dealing . . . with factors producing perception of a continuous edge, a perceived surface interior to the edge and a perceived surface exterior to the edge" (Nelson & Bartley, 1962, p. 71) i.e., O is constrained to deal with target and surround, not just target alone.

Proportionality Response

It is possible to confuse the two types of shape response just discussed with the discrimination and reporting of proportionality. In an early study, Bühler (1913) addressed the following question: Is proportion a directly perceived attribute of shape or is it a combination of height and width judgements?

Bühler's observers were asked to match different sized comparison rectangles with a standard rectangle. He found that the ratios of height and breadth were at least as accurately judged as the separate dimensions of the rectangles. Therefore, he reasoned, proportionality must be directly perceived otherwise the separate dimension error would have summed and have been greater for the proportions than for the height and width separately.

It is also known that proportionality is a response dimension having less dependence upon surrounding surfaces than shape. Nelson & Bartley (1962) found that increasing the texture of the field increased the constancy of shape but had little effect on proportion.

These responses are easy to confuse because metrical analysis of drawn shapes, matched shapes and proportional representations are all identical. In all cases it has been conventional to measure the minor (vertical) and major (horizontal) axes of a response and obtain an index number by stating the two figures as a ratio (e.g., minor axis ÷ major axis = shape, or proportionality).

Theories of Shape

Nativistic and empirical points of view have dominated shape theory. The Nativistic viewpoint is epitomized by what is called the "visual angle," "copy" or "air" hypothesis. This theoretical view concentrates on the peripheral end of the visual pathway to explain perception: The set of visual angles describing the image on the retina was an all important explanatory concept. Recent development of the Nativistic tradition emphasizes maturation in combination with a visual angle hypothesis. This trend can be called Neo-nativistic.

For the Neo-nativist, visual pathways are still essential to discriminations, but it is recognized that in some cases at least, there is a critical period for activation of these pathways. If stimulation does not occur during this period, the pathway never develops or becomes functional (e.g., Weisel & Hubel, 1965).

Berkeley argued in the 18th Century that we cannot explain depth by peripheral stimulation alone. His point was that the native basis for seeing starts as a two-dimensional surface and only the addition of images from experience allows the perception of depth. It was obvious to the later empiricists (such as Helmholtz & Carr) that perception is dependent upon functional modification of innately given nervous mechanisms. The theories of Probalistic functionalism and Transactionalism are modern outgrowths of this view.

Representative Nativistic and Neo-nativistic Positions

1. Architectural concepts. Hubel & Weisel (1962) have found that the visual cortex of the cat is composed of specifically shaped "receptive fields" which are activated by particular edges projected on the retina. A receptive field usually has a narrow straight line of excitatory points surrounded by a band of inhibitory points or vice versa. These fields appear to be innate. The most interesting conclusion of their studies for the present discussion is that each field responds maximally to a particular contour (or "edge") at a certain orientation; thus the receptive fields are highly selective and the visual system, at least in the cat, is organized so that it can code very specific and complex contour information. A possible

question for this ongoing research could be: Is there evidence that some "directions" of stimuli are more effective (e.g., are overestimated) than others? If so, and it seems as though it might be, this would substantiate Koffka's (1935) comments about the "anisotropy" of space. Koffka feels that phenomenal space is not Euclidian, it is anisotropic; it has different properties in different directions, so that figural organization is easier in the main (horizontal and vertical) directions.

2. Temporal concepts. Several psychologists have investigated timing of visual stimulation and its effects on the perception of edges and surfaces: timing is crucial, i.e., contour processes take time to develop. This work has been divided into consideration of single tachistoscopic inputs (Hebb, 1949) double inputs (Werner, 1935), and multiple inputs (Nelson, Bartley, & Wise, 1963) to the visual system.

Werner (1935) presented pairs of targets seen in sequence. One target was a solid black disk and the other a black ring whose center edge corresponded to the edge of the disk exactly. When 150 msec. elapsed between presentation of the disk and then the ring, the disk was never seen. When this succession was reversed, the disk was seen, i.e., the border contour for the disk does not have time to form in this 150 msec. interval. The ring contour processes supersede those of the disk, and since surface (difference in brightness of areas) is not perceived until contour processes are completed, the disk is not seen. Since temporal organization affects both area and edge, it should affect size and shape, since these are made up of edge and area.

In the study by Nelson, Bartley, & Wise (1963) size was manipulated by employing successive multiple inputs delivered to the eye at subfusional rates. Edges were found to form at interior positions relative to longer exposures. They sweep outward to their final position at the physical boundary of the target. In this case a symmetrical simple figure like a circular target would not change shape as the edge shifted position from the center outward because the movement is the same in all directions. But in simple non-symmetrical figures such as an ellipse, the movement in each direction changes the value of the minor/major axis ratio, i.e., the shape.

Representative Neo-empirical Experiments. Early evidence for Berkeley's empiricism came from the study of visual ambiguities or "illusions"(see for example Luckeish, 1965). Then, as now, illusions were classified as perceptual "errors," i.e., they are examples of discrepancy between proximal stimulation and appearance. There are two types of these visual errors. a) "impossible" objects which cannot be constructed i.e., different segments of the figure oppose the possibility of another segment. b) figures which appear to be distorted. A well known example of the latter is the MUller-Lyer figure. Any theory of perception must explain both types, but at present focus is on the latter.

Visual illusions are not necessarily metrically ambiguous at the retinal level. But on a purely analytical level it has to be recognized that any set of visual angles is completely ambiguous insofar as it can refer to a class of objects unlimited in number.

As Bartley (1958, p. 215) points out, "The law of the visual angle (in which phenomenal size depends entirely upon the visual angle subtended by a target) provides for an unlimited number of targets differing metrically and in geometric location producing the same perceptual end result. That is, such targets will all provide for seeing the same object." This is called the principle of geometric equivalence.

Constancy

Several well-developed theories of shape employ the concept of constancy. Despite the formal possibilities described by the principle of geometric equivalance, the empirical fact is that object characteristics appear to remain approximately constant despite shifts in the conditions under which they are seen. With the advent of the notion of constancy, functional approaches to perception began their history.

Functional theories of shape rest upon the premise that external and ideal characteristics of the target influence perception (producing the phenomena of shape constancy). Thus Thouless (1931) wrote that the shape perceived is a compromise between the retinal stimulus and the "real" characteristics of the target. The "real" aspects of the target are obvious and of course constant. Brunswik (1947) states that the regression towards what Thouless called the Real Object is from the proximal stimulus shape towards the distal object. The phenomenal (apparent) shape lies between these two extremes.

Ames (1946) and Hastorf (1950) explain stability of object perception within a transactional theory, saying in essence, that perception is a "bet" on the nature of a portion of the real world. Haan (Haan & Bartley, 1954) speaks of the "assumed object" and Ames speaks of the "transactional object" when describing the ideal characteristics of the stimulus array which cause constancy phenomena.

Cognitive Contributions to Perception: Invariance

There were a number of failures of constancy theory. The first of these is that constancy varies within a given situation depending on the type of discriminations required. Sheehan (1938) showed that subjects vary in the degree of constancy they perceive from one task to another. There is no constancy function for a given subject. Second, constancy varies greatly, depending upon the orientations of the target to the subject (Thouless, 1931). Third, over-constancy occurs (Koffka, 1935). Fourth, negative constancy (underconstancy) occurs (Koffka, 1935). This lack of a stable constancy function points up the fact that the organizing notion of an idealized Real object is faulty. The shape perceived is actually relative to the organism and the stimulus situation.

One theoretical notion that has been suggested as a substitute for constancy is invariance. The invariant object is a concept used by Koffka (1935), Flock (1964), Gibson (1966), and Graham (1965) in particular, to explain constancy phenomena in shape perception. The approach of these theorists is to state invariance of shape perception as a function determined by the physical orientation of an

object and the projected visual image. They presume that invariance operates when errors of orientation are accompanied by appropriate erros in discriminating the retinal image. Nelson (1964), has used an invariant formulation, but has restated it in terms of a relation between perceived shape and perceived tilt.

Gibson's Theory of Perception

Gibson, as just noted, is concerned with shape perception as it is related to physical conditions of stimulation. He argues for a theory of functional space i.e., a space in which perception functions adaptively. His formulations and the predictions they imply are important to the present study.

We first ought to note that Gibson's formulations were derived at least in part, from wartime experience in training pilots to land. This is important because he maintains that functional adjustment is basic to all perceptual responses. He has maintained this concern with adaptive response which he now calls "information pickup" (1966).

Gibson's theory of space perception is a psychophysical theory. Man's veridical contact with his environment is presumed to be possible because a correspondence exists between visual perceptions and the texture characteristics of the visual array.

Gibson (1950a, 1959), reviews the classic theories of perception as beginning with the mistaken assumption that the complex perception of spatial properties has no counterpart in stimulation and thus must be neurally synthesized; by intuition, by learning, or central

sensory organization. This 18th and 19th Century controversy between Nativism and Empiricism passed on to contemporary theorists the naive world of empty Euclidian space in which to study the perception of distal objects. Gibson (1950a) opposes this "air theory" of visual space with the hypothesis that there is no perception of things in space without the presence of a continuous background surface.

More specifically, Gibson (1950a, p. 3-9) set out to rectify the mistaken legacy of "air" or "point" theory by proposing that the visual world of veridical perception is a) three-dimensional, b) upright, stable, boundless, c) illuminated, colored, shadowed, textured, d) composed of surfaces, edges, shapes, interspaces, e) filled with meaningful objects. He postulates that the elementary impressions of a visual world are those of surface and edge, not "points" as in the air theory. Surface is a primitive property of the spatial world world which is given by a stimulus that can be analyzed mathematically by the methods of number theory and modern geometry into a set of variables analogous to the variables of physical energy. Thus the stimulus variable Gibson is concerned with is an ordinal, textured retinal image corresponding to the impressions of a surface.

Gibson (1950a) then divides visual space three times. He distinguishes between the visual world and the visual field (the 'field' is an analytic two-dimensional pictorial space). He then analyzes the visual world as literal (the world of qualities as they

appear to the attentive observer), and as schematic (the complex fleeting world of qualities as they appear to the inattentive, idiosyncratic observer).

Finally he dichotomizes the undifferentiated (unfocused) literal world and the differentiated (clearly focused) literal world. He states that the subject of his theory is the differentiated, literal, visual world.

Critique of Gibson's Theory

Whether Gibson's approach constitutes a theory in the sense of being an organization of empirical facts in a form that is explanatory of known facts and predicitive of new facts (Conant, 1951) is open to question. Gibson has developed certain of his postulates only partially. Specifically, an analysis in depth of his all-important concept of texture seems wanting. No precise indication is given of how elements of texture gradients interact. Also, because Gibson's visual world is one of filled spaces, he excludes, on systematic grounds, conditions of undifferentiated or otherwise impoverished surround from the study of space perception. When stressing clear, focused texture as necessary for perception, he cites evidence to show that untextured surfaces give rise to unstable, inaccurate perception (Gibson, 1948). However, a theory accounting for man's visual contacts with his surround must include consideration of his encounter with the minimally as well as the maximally textured conditions that exist in his world. Thus one may take some issue with Gibson's insistence on excluding impoverished conditions

from consideration, even though accepting the relevance of his texture-gradient variables for perception.

Boring (1951, p. 362) has made the following critical summary: "What Gibson calls a theory is thus only a description of a correlation [between texture gradients and adaptation], a theory which tells how but skimps on <u>why</u>."

However, in defense of Gibson's theory, it should be recognized that the texture gradient formulation has some explanatory (Gibson, 1966) and predictive (Gibson E., & Walk, 1960) power. Gibson and Walk have shown how effective the variables of texture gradient are for locomotor responses in infants.

<u>Veridical Processes</u>

Gibson makes a fundamental assumption that when perception is reliable and stimulus bound, it is also veridical (1950a, p. 213). In the perception of a longitudinal surface (i.e., depth) the gradient of density is given by two basic texture arrays which differ only in overall orientation of their texture elements. These are: a) width gradient (linear perspective) which is given by vertically running texture elements; b) height gradient, which is given by texture elements that run horizontally.

<u>Shape Perception</u>

Principal to the point of this paper is Gibson's treatment of shape perception, and slant and size as related to shape. Gibson (1950a, p. 170 ff.) stresses that accurate slant perception is necessary for accurate shape judgement, but at the same time denies

the classical (e.g., Koffka, 1935) implication that knowledge of the object is necessary for this accurate perception. He offers visual texture gradient as an alternative necessary condition, i.e., texture gradients provide the basis for perceiving orientation of the background and the relation of an object to its background. Stavrianos (1945), a student of Gibson's, attempted to demonstrate an invariance relationship between veridical perception of shape and slant, but generally failed to uphold the hypothesis.

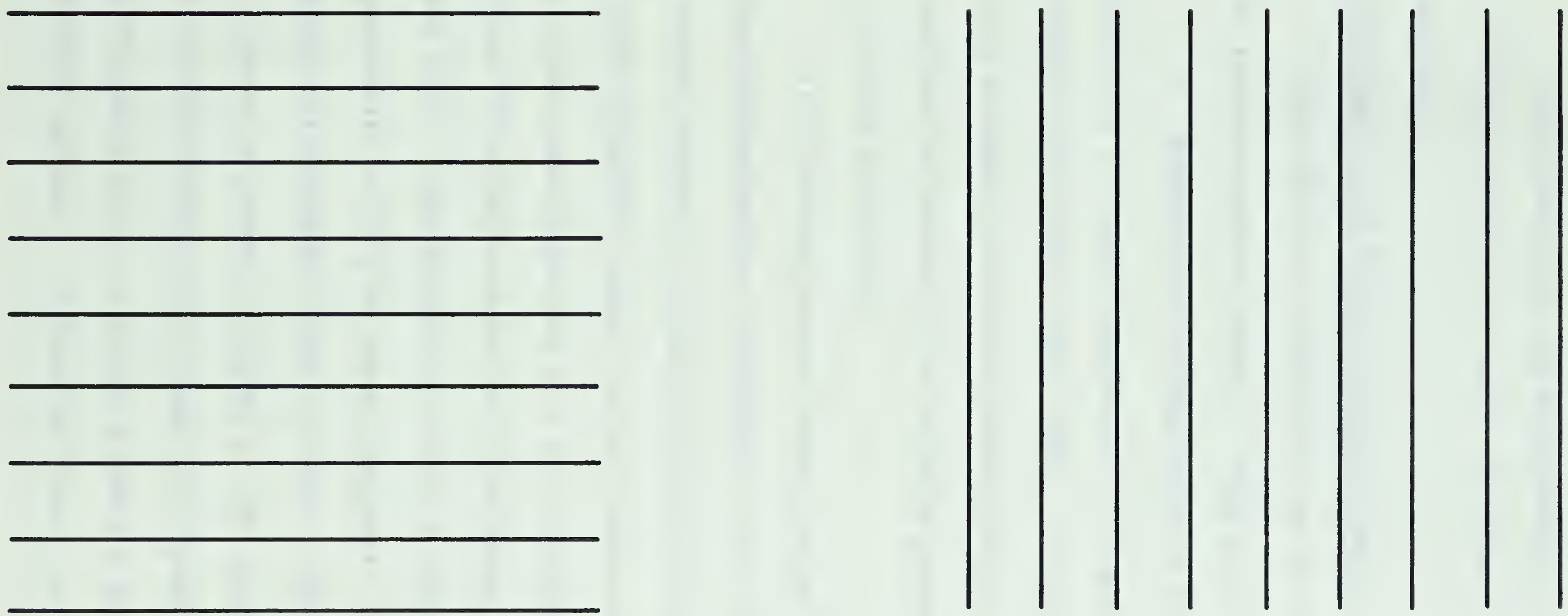
Precisely how does Gibson conceive texture and slant interaction to produce veridical perception? Gibson hypothesizes first, that in circumstances where an equilateral slanted surface is made up of identical texture elements (e.g., a checkerboard), the gross number of elements along the foreshortened (compressed height) dimension is the same as that along the uncompressed (width) dimension. Therefore, the surface shape perceived will be in correspondence with the ratio of height elements to width elements (1950a, p. 174). Secondly, judged size will be relative to "the size of elements of texture in the adjacent optical array," (1959, p. 479). Thirdly, (1959, p. 475) "the perceived depth of a target, lying at a distance on the ground, depends on the number of texture elements in that depth relative to the number in the total range of visible distance."

These three ratios together provide information concerning essential features of the real visual world. They are all ratios of one texture gradient to another.

Gibson makes no distinction between the effect of different kinds of texture-element gradients. Even the two he does distinguish, height and width gradients of density, are supposed to be equally effective in producing the impressions of distance and slant and thus have the same effect on size-shape perception (1950a, p. 89). Even if these two gradients are not precisely identical in effect, due perhaps to inhomogeneity in the retina itself, variability in experience with the gradient, or because of "anisotropy" of space (Koffka, 1935), at least their effects should be in the same direction.

Gibson's View on Height and Width Gradient in Illusions

Helmholtz (1925 edition) gives examples of specific targets which produce "illusions" (Figure 1). These examples are appropriate in the present context since they show the same characteristics as those Gibson uses to illustrate stable depth perception. The "vertical-horizontal" illusion was presented in Physiological Optics (first published in German in 1879). Gibson (1950a) apparently regards most illusions as illusory only because they are usually presented as two-dimensional figures on the undifferentiated ground of a piece of paper. His analysis suggests that targets producing the "illusions" (like those to which Helmholtz refers) will not be ambiguous as stimulus arrays in the visual world. That is, Helmholtz' illusion-producing targets possess precisely the texture gradient characteristics basic to Gibson's analysis, but Gibson holds that perception in the visual world is illusionless, reliable and veridical.



Vertical–Horizontal Illusion

FIGURE 1 A VISUAL ILLUSION PRESENTED BY HELMHOLTZ (1925, P. 193) WHOSE EFFECTS ARE OPPOSITE TO THOSE PRODUCED BY THE HEIGHT AND WIDTH GRADIENTS IN THE PRESENT STUDY

On the basis of the above analysis of Gibson's system, some consistent predictions about the effect of texture on shape can be derived.

Hypotheses from Texture Gradient Theory

Four empirical predictions can be generated for the testing of texture-gradient theory. These are:

I. Reduction of surface texture will reduce the accuracy and stability of shape judgements. This prediction is derived from Gibson's assertion (1948, 1950a, p. 211) that untextured surfaces give unstable, inaccurate perception, and (1951) that a texture gradient is necessary for reliable perception of slant, even though it is not sufficient.

II. Surface texture affects shape judgements (recognizing that overestimation, "constancy", will occur): a) Decreasing object surface texture from two-directional to non-textured will alter shape judgements toward retinal shape proportions. Basically the surface shape perceived will be in correspondence with the seen ratio of height elements to width elements (Gibson, 1950a, p. 70 and 174). Thus untextured target surfaces, insofar as they are seen accurately, will give shape judgements closer to retinal proportions than will textured target surfaces. Specifically, this prediction is based on Gibson's (1950a, p. 70) statement that "The texture of a surface faced directly does not change from coarse to fine, and correspondingly an unchanging texture gives the impression of a frontal surface." Untextured targets will be seen as having no

gradient and thus with the above reservation will be judged as projected shape. b) Targets with one-directional surface will give intermediate values of shape judgements (Gibson, 1950a, p. 90).

III. Surround texture affects shape judgements: a) Decreasing surround texture from two-directional to non-textured will alter shape judgements toward retinal shape proportions. The less differentiated is the texture between 0 and the target, the less veridical can be a) the judgement of distance between 0 and the target and b) the perceived height of the target in the field, (Gibson, 1959, p. 475). b) Shape judgements made in the presence of a one-directional (height or width gradient) surround texture will lie between those obtained from the two-directional and the non-textured surround conditions.

IV. Target texture will interact with surround texture to determine shape judgements, assuming that features of the visual world are additive. Two-directional surface and surround conditions are considered by Gibson to be most representative of the normal visual world where constancy effects are most prominent, (1950a, p. 24). Thus: a) Targets with two-directional surface, in two-directional surrounds,

will give largest (fattest) shape judgements (shape-at-a-slant affected by the tendency to constancy). b) Non-textured targets in non-textured surrounds will give smallest (slenderest) shape judgements. c) Other texture combinations should give intermediate values of shape judgements.

The following study was basically designed to test hypotheses I and II. It focused on the effects of various surface textures on shape, seen in the visual world, i.e., in a multi-directional surround.

Method

Observers

Fourteen (14) Os were used. All were of, or corrected to, normal visual acuity. The sample was drawn from third year psychology majors attending the University of Alberta.

Stimulus Conditions

The targets used to test hypotheses I and II were circles of 36 cm. diameter. (On the surround they were seen as ellipses). Target surfaces were prepared in a manner sufficient to isolate some important variables of gradient operating in the perception of slant and depth. These surfaces do not represent all the gradients discussed by Gibson but they seem to be most basic. More specifically the four target surface conditions used are shown in Figure 2.

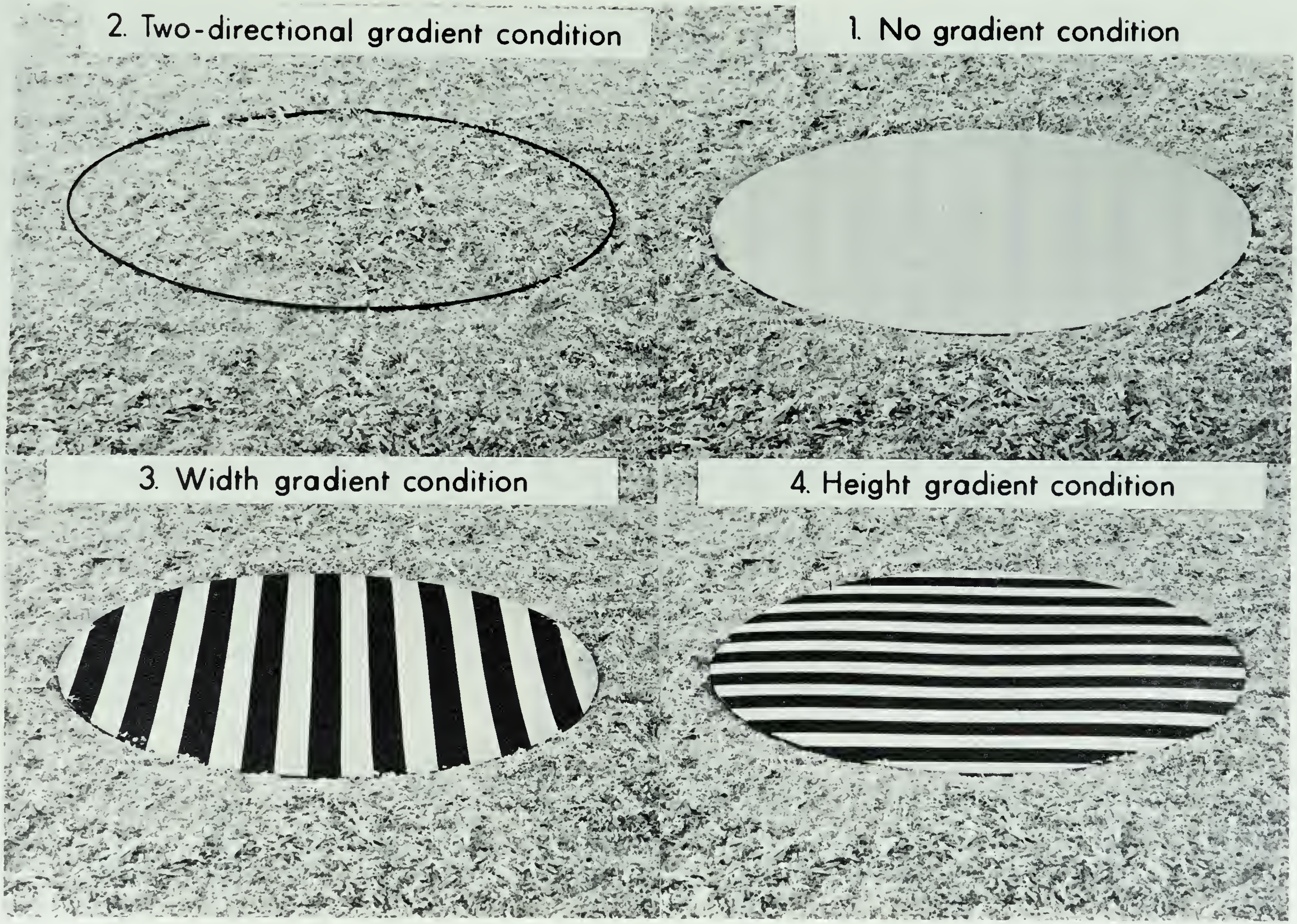
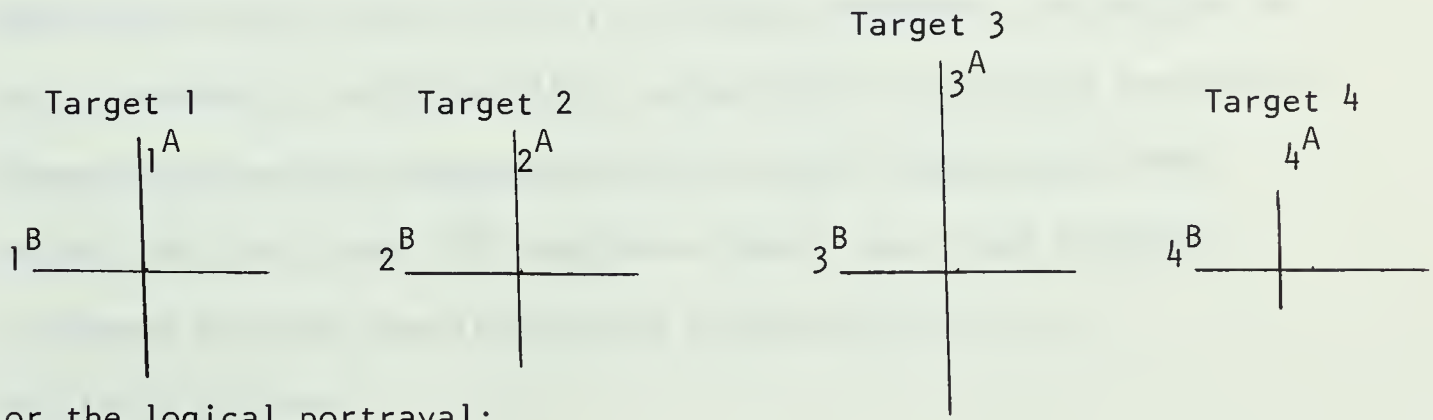


FIGURE 2 TARGET SURFACE CONDITIONS SEEN FROM 48.5 CM. ABOVE SAWDUST SURROUND AT A DISTANCE OF 145.5 CM. FROM LEADING EDGE OF SURROUND

Figure 2 Caption

Target 3 is an example of a width gradient. The width between texture elements decreases up the retina, while the height remains constant. Target 4 is an example of a height gradient on the retina. The height between texture elements decreases up the retina, while the width between texture elements remains constant.

The photographs in Figure 2 reproduce the array as seen by the O from a height of 48.5 cm. when each of the 4 targets were positioned 145.5 cm. from O's end of the table. (See method section). Since all targets possess circular contours they all possess the same Real and stimulus properties as contours. More specifically, the Real shape is 1.00 and the stimulus shape is .29. However as can be seen, the shape properties vary. The average O (see results section) sees the two-directional gradients and the no-gradient targets (targets 1 and 2), as having similar shapes, despite the fact that they possess quite different texture characteristics, and Os see the width gradient and height gradient targets (targets 3 and 4) as being of greater and lesser shape respectively as compared to targets 1 and 2 even though each contains just one gradient dimension. The following pictorial schematization may be made:



or the logical portrayal:

$$1^B = 2^B = 3^B = 4^B$$

$$3^A > (1^A \quad 2^A) > 4^A$$

1. "No gradient condition": A matte finish white disk. This target has no appreciable height or width gradient, i.e., the edge describes a shape essentially lacking in texture.
2. "Two directional gradient condition": A thin (1/32") wire soldered in a circular shape, painted flat black. The black edge describes a shape with a surface having texture gradient properties identical with the surround. Thus, on the multi-directional surround used, this ring has at least a two-directional texture (height and width gradients combined). Actually, there are unlimited gradients in this least abstract condition.
3. "Width gradient condition": A matte white disk with black edges (1" wide electricians' tape, 1" gap) upon it that extend away from the observer. In this target the width gradient (linear perspective) is emphasized and it has no appreciable height gradient.
4. "Height gradient condition": A matte white disk with the same black edges extending at right angles to the line of regard. This target emphasizes the height gradient with no appreciable width gradient.

Hypothesis I states that reduction of surface texture will decrease accuracy and stability of shape judgements. According to this hypothesis, the no-gradient target (#1) should give inaccurate shape responses when compared with the other targets, and the height (#4) and width (#3) gradients should give less accurate responses than the two-directional gradient (#2), i.e., $\#2 > (\#4 \; \& \; \#3) > \#1$.

Hypothesis II states that shape judgements will be related to texture of target surfaces so that: a) Target 2, having both height and width gradients combined, will give fattest (most overestimation) shape judgements of all the targets. b) Target I, with untextured surface, will give slenderest (least overestimation) shape judgements. c) Targets 3 and 4, with one-directional surface gradients, will give intermediate values of shape judgements.

The "two-directional" surround texture used in this study was produced by framing a 16' x 4' table top so as to make a well 1" deep, which was then filled level with coarse sawdust. Rip-cut sawdust obtained from a lumberyard produced a highly visible overall texture combining balanced height and width gradients of density (see Figure 2).

All targets were viewed from a chinrest with eyelevel at 48.5 cm. above the end of the surround, at 5 different distances on the horizontal plane (equidistant from each side of the surround). Varying target distance is the most natural way of varying the inclination of objects placed on the gravitational horizontal. These distances, measured in cm. from table edge to leading edge of target were: 36.5, 91.0, 145.5, 254.5, and 363.5 respectively. This includes Thouless' (1931) range of distances, but begins 18 cm. before and extends 200 cm. beyond those used by Thouless. (For diagram of this setup see Thouless, 1931, p. 340). Observers sat on a stool at the end of the table so that their chin rested comfortably in the chinrest.

The experimental area (8' x 24') was lighted at classroom levels by fluorescent fixtures hung 6' above the viewing table. The walls of the experimental room were of brick and plaster painted a light beige. In order to provide conditions for visual world perception as per Gibson's theory, no real attempt was made to introduce field controls or to eliminate chance objects. And thus the presentation in this study was binocular with unfixed head and no reduction screen, so as to approximate the "fully" enriched visual world.

Procedure

Observers were instructed as follows:

> Draw the shape you see as accurately as possible. Remember that it is a representation of what you perceive that you are to report with your drawing. Use both eyes, don't make any attempts to correct for 'error' in vision, such as squinting or closing one eye. Just draw a shape having an area whose proportions are identical to the shape you see in the field. Make any corrections or erasures you wish. Concentration on the target in the field will improve your drawing quickly. This is not a timed perception, so make each drawing as accurate a representation as you are able.

Each O made two experimental runs with about a 45 minute break between, during which time he rested and another began his first run. Before the first run, O practiced the drawing task until he produced personally satisfying drawings. A third experimental run was made 24 hours later. Each run consisted of 20 observations: One observation each of four targets randomly

presented at five distances. A separate random order was generated for each run and all Os received the same order of presentations.

Each response was made on a separate sheet of white, matte finish paper (8 1/2" x 5 1/2"). Admittedly, drawing shape responses on a white sheet is a very different thing from the perceptual response to the shape in the surround. Any experimental response is an abstraction, and is so limited, but drawing is a common everyday response and seems to be as good as any other representation commonly used.

Observers made a total of 60 responses. The major and minor axes were measured (mm.) to the outside edge of the elliptical drawings and a ratio computed giving a shape index for each.

Table I

Analysis of Variance Summary

Source	df	MS	F	# of error term
Run (R)	2	437.64	5.68*	1
linear component	1	852.64	11.06**	1
Target (T)	3	2021.27	37.15**	2
Distance (D)	4	53850.63	165.93**	3
linear component	1	214564.26	661.13**	3
Observers (O)	13	4097.62		
1 O X R	26	77.11		8 + 10 + 11
2 O X T	39	147.38		9 + 10 + 11
3 O x D	52	324.54		8 + 9 + 11
4 D X R	8	31.07		8
5 D X T	12	48.38		9
6 R X T	6	40.73		10
7 D X R X T	24	35.70		11
8 O X D X R	104	38.32		
9 O X D X T	156	46.28		
10 O X R X T	78	41.13		
11 O X D X R X T	312	32.48		

*$P < .05$
**$P < .01$

Note: Correction for possibility of violation of assumptions regarding heterogeneity of the variance-convariance matrices did not alter the results (each f tested with 1 & 13 df, the most conservative df specified for Greenhouse & Geiser ϵ test).

Results

Data were treated with an analysis of variance 3 X 4 X 5 factorial design with repeated measures over observers (Os). The Run (trials) ($F(2,26) = 5.68$, $P < .05$), Distance ($F(4,52 = 165.93$, $P < .01$), and Target ($F(3,39) = 37.15$, $P < .01$), main effects were significant. The analysis is summarized in Table I.

The linear components of the Run and Distance effects were also significant ($F(1,26) = 11.06$ and $F(1,52) = 661.13$, ($P < .01$) respectively). The linear Run effect indicates some practice effect or a motor adjustment over time. The linear Distance effect is as expected common-sensically. However the Run X Target and Distance X Target interactions were insignificant. Also, averaged over Os, responses to each target are highly reliable ($r = .99$, 3df, $P < .01$) over runs. Hence, there is no statistical argument for unreliability of shape judgements as surface texture of targets decreased.

Table 2

Duncan's New Multiple Range Test

Applied to the differences between 4 Target means (n of observations per mean = 210. The analysis of variance for this treatment effect is given in Table I. (cf. Figure 3)

Target Means		#3	#2	#1	#4	Shortest Significant Ranges
		64.1	60.5	59.3	56.6	$\alpha = .05$
3	64.1		3.6	4.8	7.5	$R_2 = 2.40$
2	60.5			1.2	3.9	$R_3 = 2.52$
1	59.3				2.7	$R_4 = 2.60$
in order of magnitude		3	2	1	4	

Any two treatment means not underscored by the same line are significantly different ($P < .05$)

Any two treatment means underscored by the same line are not significantly different ($P \geq .05$)

The significant Target effect ($F(3,39) = 37.14$) indicates that the targets produced differential effects on shape judgements, averaged over distance and run. In order to determine exactly how targets differed, the four overall target means were tested with Duncan's New Multiple Range Test (Table 2). As Table 2 shows, target 2 (two-directional) and target 1 (no gradient) mean shape indices ($\overline{X} = 60.5$ and 59.3 respectively) did not significantly differ (shortest significant range for 2 means = 2.40, $P = .05$). But targets 3 and 4 (one-directional gradients) means ($\overline{X} = 64.1$ and 56.6 respectively) with the shortest significant range for 4 means being 2.60, ($P \doteq .05$) were significantly different both from each other and from targets 1 and 2. The width gradient target produced largest shape judgements of all targets. The height gradient target gave the smallest shape index ($P = .05$) of all the identically sized circular targets (cf. Figure 2).

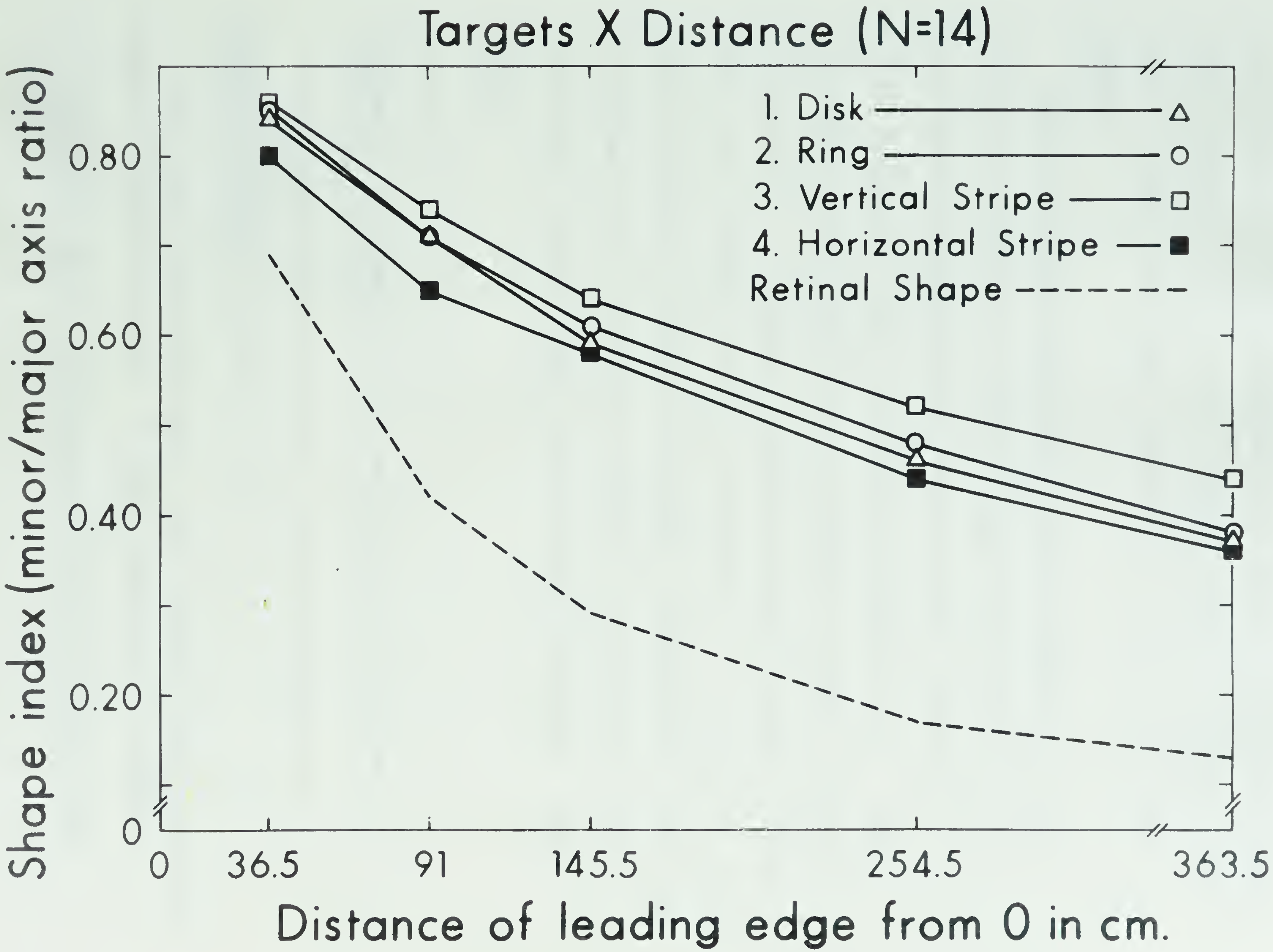


FIGURE 3 MEAN SHAPE JUDGEMENTS OF FOUR TARGET SURFACE CONDITIONS SEEN AT FIVE DISTANCES ON A SAWDUST SURROUND

The order of magnitude shown in Table 2 and Figure 3 is clearly contrary to the interpretations made from texture-gradient theory (hypothesis II). Figure 2 demonstrates the effects of the texture variables and gives face validity to the results just reported.

Moving a circular target away from the observer on a flat gravitational plane at a standard height below eyelevel produces a much greater decrease in the minor (vertical) axis of the retinal projection than in the major (horizontal) axis.[1] When the circular target used was at its farthest distance, the major axis was 20% of its nearest distance value and the minor axis 4% of its nearest distance value: A ratio of 5:1. In order to assess obvious response differences in the data, examination of individual O's responses was undertaken to determine the degree of correlation between change in major and minor axes and change in shape indices.

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[1]Distance (D) is measured from leading edge of table top to leading edge of target.

The visual angle of the minor axis = $\beta - \alpha$ where $\tan \beta = \frac{\text{D+ target diameter}}{\text{viewing height (H)}}$, and $\tan \alpha = \frac{D}{H}$.

The visual angle of the major axis is equal to the angle whose tangent = target radius (R) $\div \frac{D + R}{\sin \zeta}$, where $\tan \zeta = \frac{D + R}{H}$.

Thanks are due Mr. Thomy Nilsson for derivation of these formulae.

This indicated first that not all observer representations of change are predictable on the basis of changes input. This is shown when correlations for all judgements of all targets are calculated between: a) major and minor axis decline over distance, b) major axis decline and shape index decline over distance and c) minor axis decline and shape index decline over distance.

The mean correlation (r, z' normalized) of major and minor axis changes over distance is .51. The mean correlation of the minor axis decline with the shape index decline over distance is .96 while mean r is .10 for the major axis-shape index relation (Table C). Thus on the average, as expected, minor axis change over distance greatly contributes to shape index changes over distance and major axis change much less so. Of these correlations, plotted in Figure 4, the only one stable over runs was that between minor axis and shape index.

Figure 5 gives the frequency distribution of obtained correlations (r) for n = 5 observations of major with minor axis change over distance. Its trimodal form and extreme width suggest that several methods were used to communicate shape experience by drawing. The presence of distinctive methods in turn suggests that some types of representations involve considerable abstraction from stimulus properties or selection of available cues for judging shape.

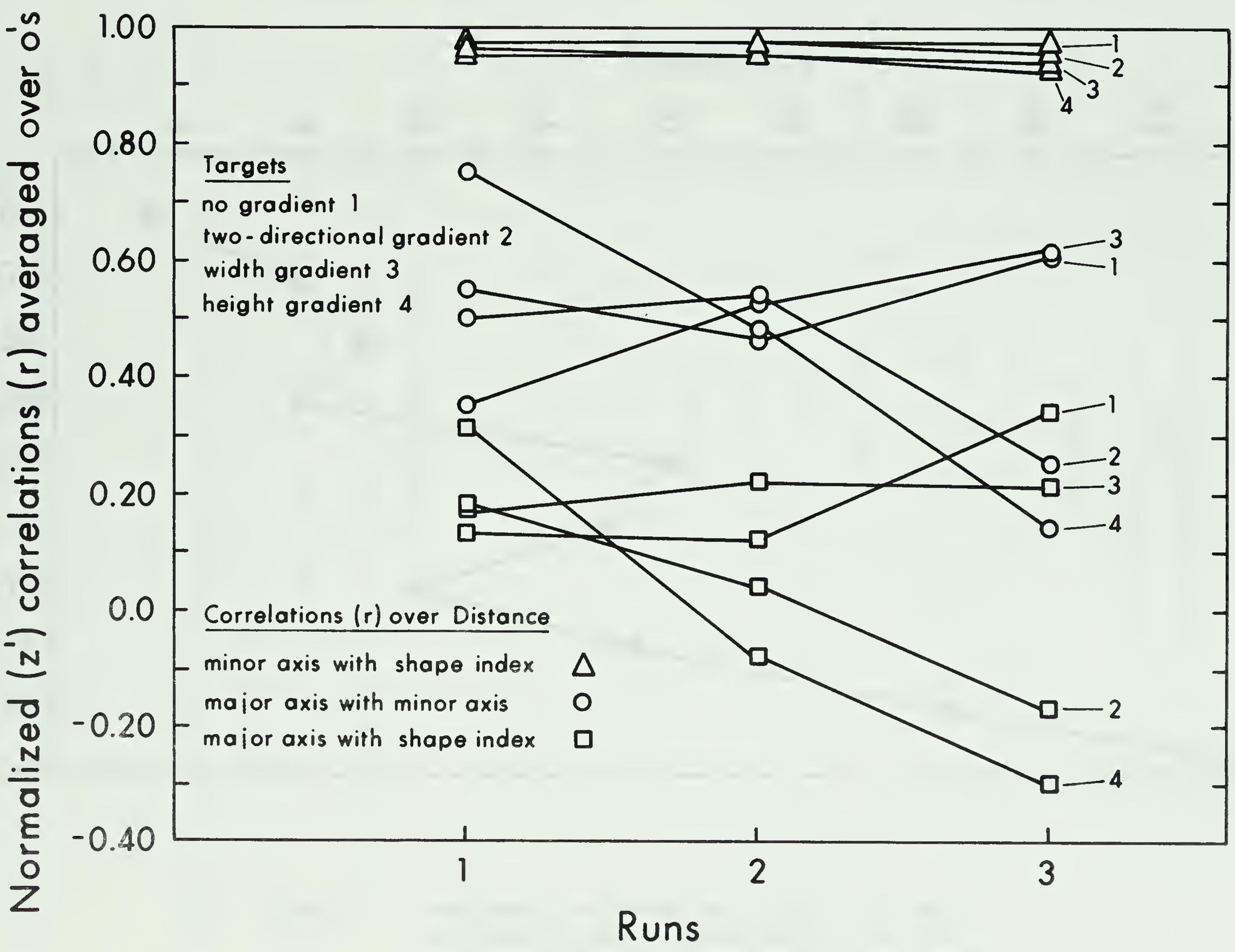

FIGURE 4 NORMALIZED MEAN CORRELATIONS OF ALL PAIRS OF SHAPE JUDGEMENT DIMENSIONS OF FOUR TARGETS

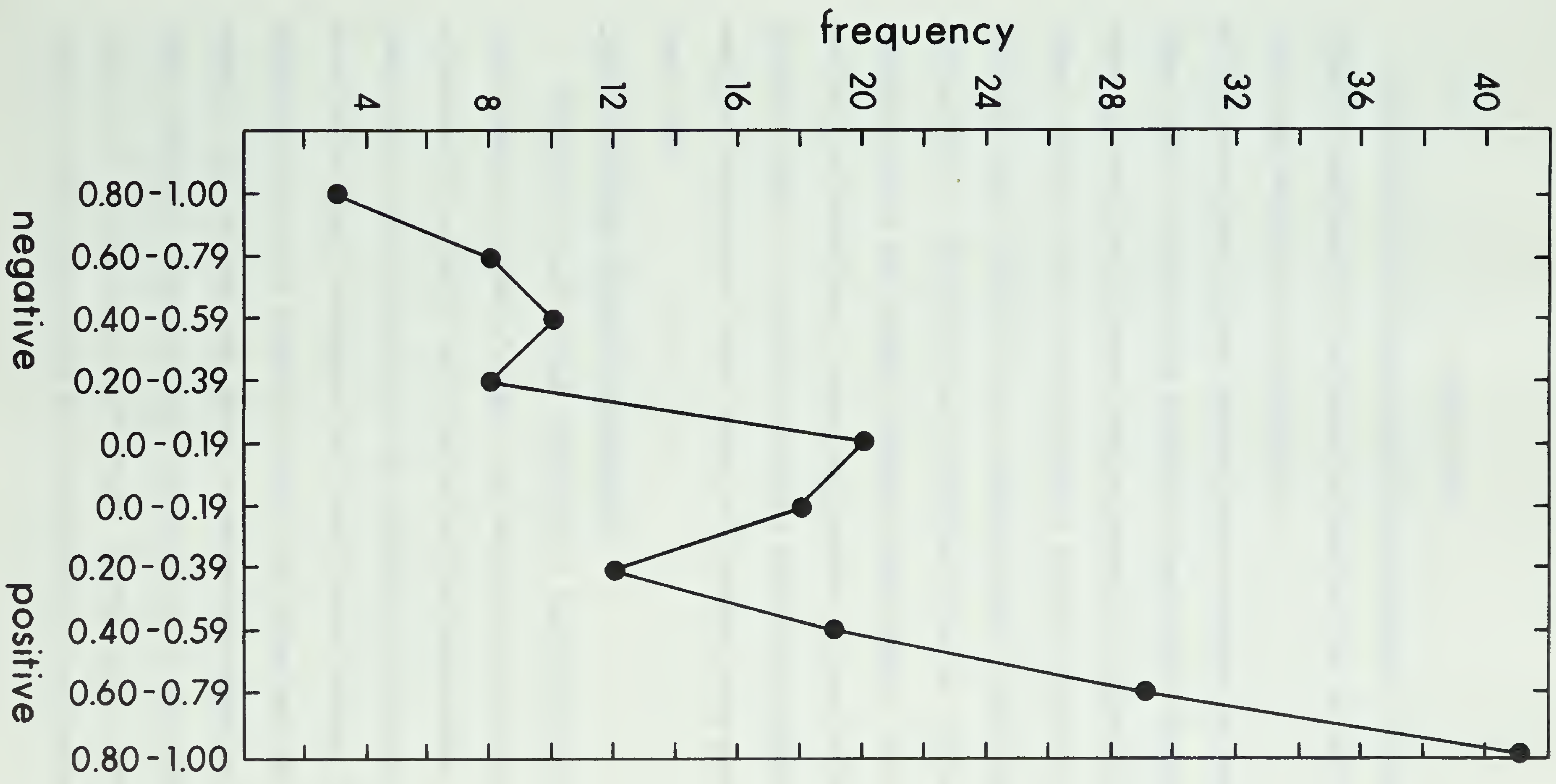

FIGURE 5 FREQUENCY DISTRIBUTION (TOTAL r's = 168) OF CORRELATION OF MAJOR WITH MINOR AXIS OF SHAPE JUDGEMENTS MADE BY ALL O's, OVER RUNS AND TARGETS

Discussion

Returning to the texture-gradient hypotheses, the expected order of magnitude of the shape indices for the targets used in this study would be the following:
a) two-directional target texture should produce the largest shape index, b) the height gradient target should essentially be equal to the width gradient target, producing intermediate shape indices, and c) the no-gradient condition should produce the smallest shape index and this index would most likely be 'inaccurate' and unstable. The data give a different picture. The width gradient target produced the largest (fattest) shape index. The shape index for the two-directional target was similar to that for the no-gradient target. The height gradient condition produced the smallest (slenderest) shape index; all indices were very reliable over runs.

Texture Gradient Theory in Retrospect

Effective visual space conceived in texture gradient terms originates as a sheaf of light rays whose cross-section is structured in a manner described by ordinal measurement. The sheaf has a single origin for the stationary retina but is extended in all directions throughout the visual field (Gibson, 1966). According to texture gradient theory, the shape seen by the observer will reflect the manner in which the target is related to other components making up the cross-section of the sheaf. One of the critical dimensions of the sheaf is that set of ordinal relations which determines the orientation of the surface or ground

on which a target rests. Within this view, "illusions" such as linear perspective and the "vertical-horizontal" illusion (Figure 1) arise because they are abstractions of stimulation usually resulting from contact with the visual world. In the experiment just reported, some important components of visual texture were presented to the eyes as targets within the visual world. It was found that texture gradient analysis did not predict phenomenal space. Horizontal and vertical retinal gradients of stimulation were not equivalent in their effect upon shape. And insofar as the ring target #2 represents a combination of the vertical and horizontal retinal gradients, these gradients are also not additive in their effect on shape. Gibson's theory does not appear to function even on a correlational level since effects are opposite to the direction expected. The theory fails to predict order of shape indices in even the most gross manner.

Even though the shape indices obtained from the Os judgements were very stable and reliable over runs, it appears, in retrospect, that Os exhibited surprising individual differences in mode of shape response. Since the instructions emphasize that the drawing was to be an accurate representation of the target as seen by O, one would expect O's drawings (irrespective of drawing ability) to reflect to some extent the size changes in both axes as distance of the target is varied. Actually, however, the reproductions made by the observers do not do so.

The results suggest, and inspection of individual response records bears this out, that although in all cases the minor axis change over distance accounts for most of the change in shape index over distance (Figure 4) the Os used three methods of expressing shape by drawing (Figure 5). The methods are as follows:

Method I: Decreasing target shape is represented by increasing the size of the major (horizontal) axis as distance increased. This results in a high negative correlation with the declining minor axis.

Method II: Decreasing target shape is represented by stabilizing the major axis over distance. Anchoring the major axis near one arbitrary value results in a zero or approximately zero (.30 to -.30) correlation with minor axis change. This is the type of representation one would expect if the shape judgements were stimulus bound (i.e., no abstraction).

Method III: Decreasing target shape is represented by decreasing the major axis over distance. This results in a high positive correlation between major and minor axis change.

In Figure 3 the curves for shape judgements are different than that describing the retinal projection values. Since the shapes are "overestimations" (fatter ellipses) it superficially appears that this difference can be explained as due to shape constancy (shape judgements are free to vary from the value of the retinal projection to 1.00, the value for a frontal circle). However,

even though the shape values fall within the range expected by constancy theory there are the following inconsistencies. The constancy index (computed as judged shape - retinal shape ÷ 'real' shape-retinal shape; 'real' shape = 1.00) is neither a constant value for each texture gradient condition, nor is variation in constancy index a constant value for the different distances. Thus, constancy appears to have limited if any explanatory power.

The mere occurrence of the analyzable elements of texture gradients did not explain or exhaust the functional correlates of the field for the human perceiver. This may seem trivial since it seems to be characteristic of much of scientific analysis, e.g., neither does the occurrence of H_2 and 0 state all the functional characteristics of "water" of significance to humans. However, there is perhaps a special difficulty arising here since we are studying the symbol-maker and not merely the symbol. Let us therefore examine more closely Gibson's outlook upon visual end results.

Gibson assumes at least two things about the relation of the perceiver to the visual surround. The first of these is that the "literal world" (the world of surfaces, edges and shapes) can be treated as distinct from the "schematic world" (the world of fleeting impressions of the inattentative idiosyncratic observer). And in the literal world all visual end results have a veridical tendency because perception essentially serves biological adaptation.

The opposite is not true for Gibson, i.e., schematic perception is not separate from literal perception because, he says (1950a, p. 199),

> the world of symbolic meanings (a world of constructed meaning) stands at a far extreme from the world of surfaces, edges and shapes....Nevertheless they are both the same world. Things must be substantial before they can be significant or symbolic.

The results of this study do not support his premise that the literal factor has primacy over schematic, if in fact the theory of texture gradients is a useful description of the world. These results point instead to a strong interaction between the phenomenal (schematic) and literal world. Also it seems that elements taken from the texture gradients making up the visual world are utilized for shape perception in rather personal ways. That is, the schematic world also shows the effects of functional modifications of perception due to past experience.

Gibson's second assumption is that the visual world is isomorphic with the Euclidian "world" and that all adjustments are made in accord with the "real" Euclidian space. This may be accepted provisionally for a flyer adjusting to the world from a jet, but the flyer is in an exceptional situation necessitating continual functional adaption. The same is perhaps ideally true for the driver of a car. Visual appreciations of a qualitative nature may not need to play by any such rigid rules, however.

The very presence of other geometrical and mathematical analyses, like Rudolph Luneberg's (1947) conception of perceptual space as a hyperbolic non-euclidian geometrical space, suggests that other appreciations are possible, or at least that the world of fact is not completely known or represented by any one system. It is certainly not necessary to assume that texture gradients are correlates only of the Euclidian world. They may in fact be surrogates of other spaces.

In adaptive circumstances (those requiring motor adaptation) space may be Euclidian, while circumstances permitting passive discrimination may produce other types of space. This general interpretation is supported by our data since the presence of textures did make a difference, although as said not in ways expected by texture gradient theory.

Another interpretation could also be made. One might say that these differences occur because the different textures produce a filled space which is anisotropic in its main directions (Koffka, 1935) i.e., it is differentially effective in a vertical direction. This study provides no basis for speaking to this question.

The differences in method of representing seen shape in this study indicates that we are not dealing with combinations of isolated horizontal and vertical line length judgements. They indicate instead that the differences in response reported here

are products of organization. Work reported by Bühler (1913) is consistent with this evaluation.

Though it can only be offered as a suggestion at this point, some pilot data were collected relating to hypotheses III and IV. It will be recalled that hypothesis III dealt with the effect of varying surround texture on shape judgements, and hypothesis IV with the additive nature of the effects of surface texture and surround texture.

A short series (5 per surround) of judgements of the no-gradient target (#1) was made on two different surrounds by one-half of the original Os (n = 7). A one-directional surround was produced with black edges (1" wide electricians tape, 1" gap) running parallel to the observers' line of regard on an unbleached muslin cloth. A no-gradient surround was given by unbleached muslin stretched on the 16' X 4' table. For Figure A, data for the two-directional surround was from the principal study. Each O made 5 responses to target I on each pilot surround. Figure A presents the results graphically and Table B is a summary of the analysis of variance of the pilot data only. The different surrounds appear to have had no effect on shape judgements of the no-gradient target. Perhaps further research will examine the implication here that the target effects obtained in the principal study were not fixed by the presence of the textured surround but by the texture characteristics of the targets themselves.

Gibson's field dependence theory seems to demand that the field behaves in such a way as to establish the perceptual character of objects located within it. If so, the anchoring of the horizontal axis relative to the great change in the minor axis would not vary with practice. As was mentioned before, and as Figure 4 illustrates, the correlation between major and minor axis decline does change over three runs and it also seems to vary with targets. Thus another explanation than field dependence must be presented. Quite possibly some sort of change in adaptation level will explain the changing horizontal axis anchor i.e., experience anchors the horizontal axis and thus the anchor varies with number of Runs. Such an explanation in terms of a judgemental process will fit the individual difference results of the present study much more completely than a biological adjustment theory.

Another comment pertinent to this question of the effect of the field on at least one target condition, is made by Clark, Smith and Rabe (1956, p. 4) who say "when the textures of the ground and surface of the figure are similar, the enclosed area may assimilate with the ground...." Our two-directional target condition could easily have assimilated with the surround. But rather than offering any difficulty for veridical accurate observation this should, following texture gradient principles, strongly aid such veridical perception. If so, target 2 should

have produced the largest (most influenced by constancy effects) shape indices. But as mentioned, it took an intermediate position. Perhaps the seemingly strong (as implied by Gibson) sawdust texture did not give a perceived two-directional surface at all.

Conclusion

Gibson's stress on veridical perception denies the object as a personal creation, stressing instead that external "facts" determine perception. The present results suggest that a person's world is not a world of fact but partly a world of personal construction. The world of fact is dependent on the situation one is in; it is probably impossible to state a-priori what the "real" world is. The examination of individual response data shows that Os did not behave in as simple and straightforward a manner as is predicted from a functional outlook. Rather, their responses seemed to be complex organizations of an interaction between each observer's phenomenal world and the literal world.

Gibson's expectations of simple stimulus bound responses comes from his assumption that perception is an adaptive response determined by common properties of the human tissue system and by the "real" world. From other positions such as that of Brentano (1874), Gibson's distinction between the literal and schematic world is incomplete: the perceptually objective world must contain the intentions of the observer. In unstructured situations like the observation setup used in this study, which require little in the way of adaptation, seeing seems indeed to have a personal referent.

Finally, these differences in response appear as creative acts from another point of reference. Every observer has personal and culturally influenced experiences with abstracting relevant

cues and communicating preferences about his world. These experiences seem to combine to produce modifications of the person's world as we come to know it through his responses. A more modern point of view also stresses the same point. Witkins (1949) names two characteristic types of perceiving, "field adherence" and "field independence." Using his terminology, method II would be field adherent and the other strategies to a large extent field independent. Thus even within the known regularities of human perception (including this study's results), people in many circumstances are seen to attend and respond to a world partly of their personal creation. This is true even when their "creation" is just selective attention (and/or supression) to different cues in the field.

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Table A

Analysis of Variance Design

for principal study

Column effects	df	Row effects	df	Total df
		Observers (O)	13	
Runs (R) (Fixed)	2	O X R	26	
Targets (T) (Fixed)	3	O X T	39	
Distances (D) (Fixed)	4	O X D	52	
D X R	8	O X D X R	104	
D X T	12	O X D X T	156	
R X T	6	O X R X T	78	
D X R X T	24	O X D X R X T	312	
Σ	59		780	839

The column effects are tested with the row effects opposite.

Table B

Analysis of Variance: Pilot Study

Source	df	MS	F
Surround	1	17.49	
Distance	4	4277.48	54 .33**
linear component	1	16940.00	215.10**
Observers (0)	6	1469.33	
Surround XO	6	25.10	
Distance XO	24	78.73	

**P $<$ .01

Note: The sawdust surround was not analysed with the two surrounds used in the pilot study.

Table C

Normalized* Correlations (r) for n = 5 observations of decline over distance, weighted averaged over 14 Os

Target	min.- maj.	maj.- s.index	min.- s.index	min.- maj.	maj.- s.index	min.- s.index	min.- maj.	maj.- s.index	min.- s.index	min.- maj.	maj.- s.index	min.- s.index
	RUN 1			RUN 2			RUN 3			RUNS COMBINED		
#1 (no gradient)	.55	.13	.95	.46	.12	.97	.61	.34	.97	.54	.20	.97
#2 (two-directional)	.50	.18	.95	.54	.04	.95	.27	-.17	.94	.44	.02	.95
#3 (width gradient)	.35	.17	.97	.53	.22	.97	.61	.21	.96	.55	.20	.97
#4 (height gradient)	.75	.31	.96	.48	-.08	.95	.14	-.30	.95	.49	-.02	.96
weighted $\overline{X}$ r's	.58	.20	.96	.51	.08	.96	.43	.02	.96	.51	.10	.96

*Note. The obtained distribution of correlation coefficients was normalized with a z' transformation.

Table D

Means for Targets and Runs by Distance

(averaged over 14 Os)

Distance (cm)	Run	Disk #1	Ring #2	Width #3	Height #4	Distance $\bar{X}$'s
	1	83.3	83.6	84.9	79.6	
36.5	2	83.9	83.5	86.4	80.4	
	3	84.4	87.9	86.9	80.3	
	$\bar{X}$	83.8	85.0	86.1	80.1	83.7
	1	70.1	72.1	73.4	64.3	
91.0	2	68.9	68.1	74.1	65.5	
	3	73.5	73.2	74.7	66.2	
	$\bar{X}$	70.8	71.1	74.1	65.3	70.3
	1	57.4	61.1	65.7	55.4	
145.5	2	59.9	60.4	61.7	59.6	
	3	59.2	61.1	65.7	58.0	
	$\bar{X}$	58.8	60.8	64.4	57.7	60.4
	1	46.5	45.4	50.6	40.4	
254.5	2	44.8	48.6	52.4	45.7	
	3	46.6	48.6	54.4	47.1	
	$\bar{X}$	46.0	47.5	52.47	44.4	47.6
	1	36.0	36.0	43.2	31.6	
363.5	2	37.4	38.8	43.4	34.9	
	3	38.2	39.3	44.0	40.5	
	$\bar{X}$	37.2	38.0	43.5	35.7	38.6
Target means		59.3	60.5	64.1	56.6	60.1

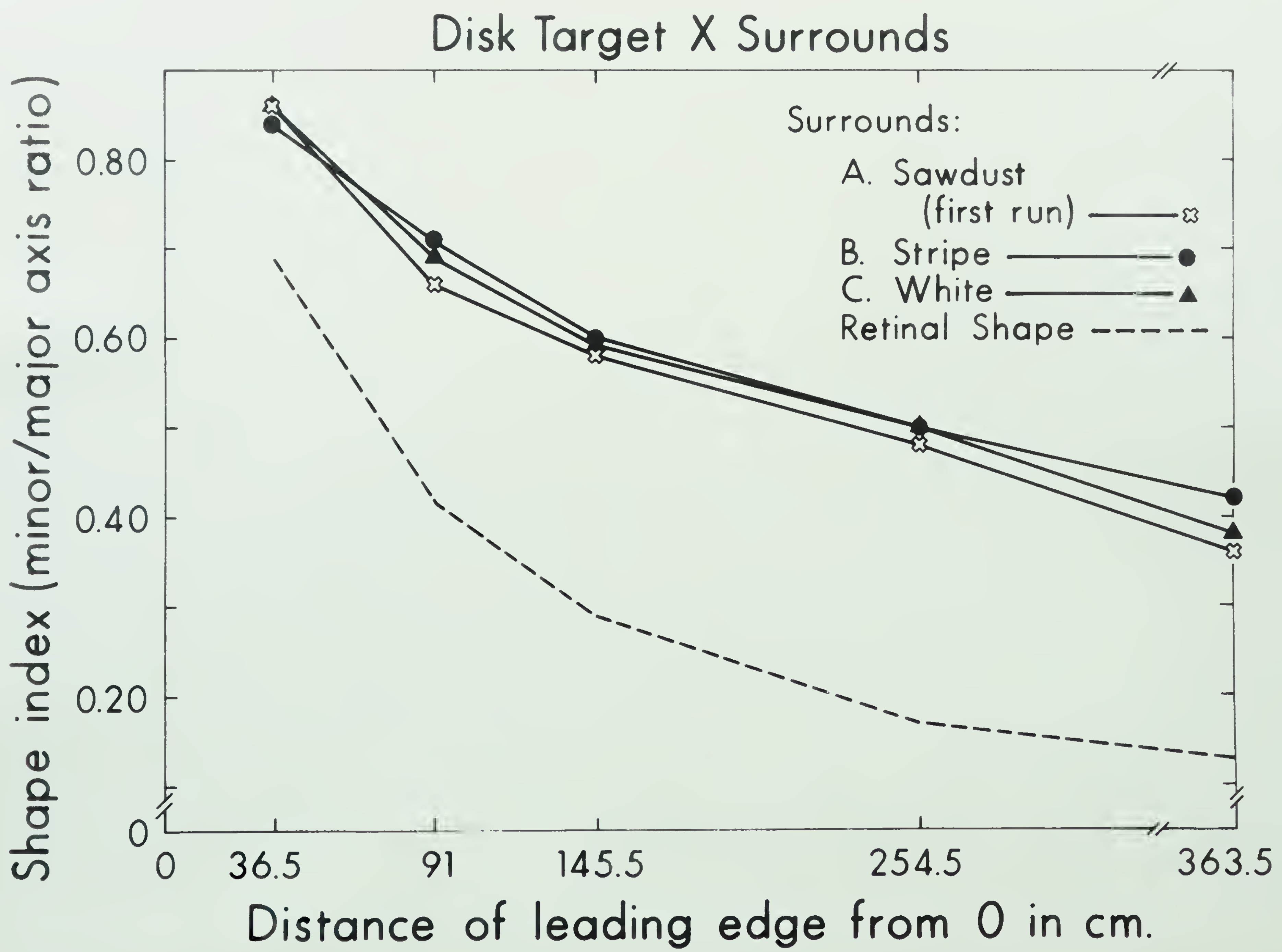

FIGURE A   MEAN SHAPE JUDGEMENTS OF THE NO-GRADIENT TARGET CONDITION SEEN AT FIVE DISTANCES ON THREE SURROUNDS